Changes of community characteristics of a broad-leaved-conifer mixed forest after selection cutting[1]

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Abstract The modification in structure, composition, and diversity, shrub, as well as herb strata of *Pinus koraiensis-Tilia amurensis-Abies nephrolepis* forest after 16a of selection cutting in northeastern China was studied. In the selection cutting forest, individuals with small DBH classes characterized size distribution. The virgin forest, on the other hand, was mainly composed of individuals having larger DBH classes. The density of dominant species and the species diversity at tree stratum in the selection-cutting stand was significantly larger than that of in the primeval forest. The shrub layer also showed a similar result. However, the herb layer had comparatively low species diversity. Large growing space and strong light in the artificial gaps must have provided opportunities for the species of shade tolerance or shade intolerance to establish on the stand. The juveniles of non-pioneer species, which were hardly found in highly shaded virgin forest, were also released by the disturbance. Regeneration in the selection-cutting stand was prompted by the disturbance, where the density of saplings occurred nearly 3 times as much as that in the virgin stand. The growth of shrub layer was improved due to the alteration in light condition. The projection volume of the herb layer was less affected. Restoration of a semi-virgin forest to the original status after selection cutting could be possible in several decades. However, for those subjected to clear cutting, it might take several centuries. In order to promote biodiversity, it is reasonable to practice selection cutting in communities for consisting of species with various levels of shade tolerance.

Key words: Changbai Mountain, Selection cutting, Regeneration, Species composition.

Introduction

Species diversity is affected by natured disturbance, such as wind and fire in various ways, mostly depending on gap size and gap density, as well as disturbance frequency (Poulson *et al.* 1989). However, an anthropic disturbance such as clear cutting in large area may lead to the diversity in the lowest level and the simplest structure, while a proper selection cutting regime may help release the individual suppressed under the canopy (Canham 1988). Cutting, especially also brings modification in vertical strata and species composition as well (Elliott *et al.* 1994). Studies on disturbance-diversity are meaningful in forest management and natural conservation. However, the conclusions are not the same as conflicted hypothesis which have been proposed in relation to the vegetation diversity and successional status after disturbance (Huston *et al.* 1987).

For the forest in this region, clear cutting in large area had been a normal practice in forest management until selection cutting was proposed in 1950's (Liu 1957). Selection cutting of a forest combined by various species with different ecological characteristics has been considered to be effective in maintaining biodiversity while meeting the needs.

Studies have indicated that succession consequence chang according to cutting systems. A secondary forest dominated by *Betula platyphylla* and *Populus davidiana,* will emerge after the clear cutting of primeval forest, while the composition may remain intact when subjected to selection cutting (Zhang *et al.* 1983). Some studies have also shown that species diversity can recover to preharvest's level after clear cutting (Gilliam *et al.* 1995).

The broad-leaved-conifer mixed forest in northeastern China is known as the climax vegetation, and occupies a large area in the region. The forest has been playing an important role in maintaining biodiversity and ecosystem stability, as well as supporting the economic development. During 1950's, its management ways through cutting regeneration system were discussed (Qian 1958), which eventually lead to a drastically argument till late 1960's. The discussion was mainly based on the shade tolerance of *Pinus koraiensis,* a leading species of the forest and biodiversity change. In this paper the effect of selection cutting on the forest ecosystem, particularly the structure and diversity was discussed.

Methods and study area

The study area was located in Heping Forest Farm, about 10 km south of the Changbai Mountain. The elevation was 940 m, and the topography was nearly flat with some slope degrees less than 5°.

The selection cutting was held in virgin forest of *Pinus koraiensis-Tilia amurensis-Abies nephrolepis* in 1975, and

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the cutting rate in basal area was about 50%. In the studied plot, however, the selection-cutting intensity was estimated for less than 30% in basal area by measuring the stumps.

A plot of 0.25 hm^2 was set in both the disturbed (selection cutting) and non-disturbed (virgin forest) stands. The distance between the two plots was about 200m, and the site condition was almost homogeneous with a flat land feature. Data of diameter for all trees with DBH above 3.0 cm were recorded. Ten quadrates ($16m^2$) were set in each plot with shrub layer. The height and crown width were measured. Same number of quadrate ($1m^2$) was set for herb layer, where the coverage was estimated, and the number of individuals and the dominant height of every species were recorded. Based on the data, Shannon-Wiener diversity index, Simpson dominance index, Morishita similarity index and Pielou evenness index were calculated. The significance difference of diversity index between the plots of disturbed and non-disturbed stands was determined by *t*-test (Magurran 1988), the dominant species were determined from "dominance analysis" (Ohsawa *et al.* 1985).

Results

Comparison of stand structure

The number of individuals with DBH more than 11 cm in the control stand was 92 stems (368 stems/hm^2) before the selection cutting and was 76 stems (304 stems·/hm^2) in the selection-cutting stand. 13 stumps were found in the plot, with basal area of $2.13m^2$, the density of the selection-cutting stand was nearly equal to that of the control plot. Therefore, it could be considered that the stand structure was comparatively uniform or homogeneous before selection cutting. The current stand density of individuals with DBH≥3.0 cm in the selection-cutting stand was 350 stems (1400 stems/hm^2), and significantly higher than that in the control plot which had 176 stems (704 stems/hm^2 in Table 1). This difference revealed that the density was decreasing with basal area increasing during the progressive succession, due to the competition for growing space among individuals. This result compiled with many previous studies such as Sundriyal *et al.* (1994), Saxena *et al.* (1984), and Primack *et al.* (1985).

The DBH distribution of the whole stands showed "J" shape in the two plots. However, the number of young trees (DBH<11cm) in the selection cutting stand had a large proportion (61%), DBH class was over times of the adjacent DBH class. On the contrary, the number of younger tree in the uncutting plot was low (21%), and the DBH class was even less than the adjacent DBH class (Fig.1). It could be interpreted from this distribution model that the seedlings and saplings on the selection-cutting stand were released due to the light alteration. The basal area in the non-disturbed and disturbed plots was $12.68m^2$ and $7.16m^2$, respectively. This indicated that the productivity took decades to recover.

The canopy layer in the control plot could be divided into two sub-layers of 26m and 15m respectively. The vertical closure, especially in the understory, was lower with a good visibility. While the vertical structure of tree stratum in the selection cutting plot was almost continuous because of the existence of enormous young tree under the overstory, and this could also be reflected by the size distribution (Table 1 & Fig.1).

The shrub layer was well developed in the disturbed site. The crown projection volume was $82m^3$, considerably higher than that in the control plots which was $50m^3$. The coverage was 50 % in the disturbed site and 35 % in the control. The average height of the shrub layer was of 100 cm and 70 cm in the selection-cutting plot and the control plot respectively (Table 2). If we consider the projection volume as the representative of productivity, the growth of shrub layer was essentially improved.

The productivity of herb layer in the disturbed plot seemed to be suppressed by the well-developed shrub layer. Consequently the herb layer in the selection cutting site was poorer than that in the control, and the projection volume was nearly half of that in the control (Table 3). This result showed that the stratum was controlled by the nearest layer and the higher strata, and it also supported conclusion that herb layer recovered slower than other strata after disturbance (Meier *et al.* 1995).

Comparison of species composition

The number of species in the disturbed plot was 15, and 12 in the control plot (Table1). The individuals with DBH<11cm were recruited during 16a after selection cutting, and apart from the large-sized-shrub species, such as *Acer ukurunduense*. It was clear that the number of tree species was almost the same in the two plots, 9 species in the uncutting plot and 8 species in the disturbed stand. The species composition was reorganized after the disturbance. During 16-year recovery period, the number of tree species increased to 14 which was 55%, and more than that of before selection cutting and in the control plot. This result showed that a manipulated disturbance could help to increase the species richness by reducing canopy closure and creating longer forest edges. Some species of shade intolerance appeared after the disturbance. For instance, a typical light demanding species (*Betula platyphylla*) was established in the site soon after the selection cutting. *Similary, Maackia amurensis, Padus asiatica, Larix olgensis* etc. were also new components to be released after the canopy thinning (Table 1, Fig.1). The establishment and maintenance for non-pioneer species was closely related to disturbance. Comparing to the control plot, the species richness in selection cutting stand was lower in the later phase, and higher in the early one. Due to the lower richness in the late phase old growth was considered as the result of canopy suppression that limited the survival and growth of the shade intolerance species, as well as some of

the climax species.

The number of dominant species, in the selection-cutting plot was significantly larger than that in the control plot, 8 and 3 respectively. *Tilia amurensis, Pinus koraiensis* and *Abies nephrolepis* were dominant species in both the selection cutting and control plots. Also, some shade intolerance and accompanying species posed as dominants in the selection cutting stand, like *Betula platyhylla, Maackia amurensis, Populus ussuriensis, Padus asiatica* (Table 1) and so on. The number of dominant species with importance value was the same between the two plots, each with 4 species, but in basal area there was only one dominant species in the selection-cutting stand, versus 3 in the control.

Table 1. Tree species composition in the disturbed and original plots.

	Logged					Unlogged				
Species	DBH /cm	N	BA%	N%	IMPO	DBH /cm	N	BA%	N%	IMPO
Pinus koraiensis	38.3	33	65.7*	9.4*	75.1*	40.5	16	19.3*	9.1*	28.4*
Abies holophylla	10.9	66	10.5	18.9*	29.3*					
Tilia amurensis	8.5	50	9.5	14.3*	23.8*	50.8	21	36.5*	11.9*	48.5*
Acer mono	18.6	12	5.5	3.4	9.0	14.2	12	1.9	6.8	8.7
Ulmus japonica	23.5	2	2.1	0.6	2.7	17.0	8	1.6	4.5	6.1
Populus ussuriensis	8.1	22	1.7	6.3*	8.0	9705	4	24.4*	2.3	26.7*
Abies nephrolepis	5.2	35	1.4	10.0*	11.4	10.2	96	8.0	54.5*	62.5*
Betula platyphylla	4.5	56	1.3	16.0*	17.3*					
Padus asiatica	5.4	18	0.7	5.1*	5.8					
Juglans mandshurica	22.7	1	0.6	0.3	0.9					
Maackia amurensis	4.2	28	0.6	8.0*	8.6					
Acer tementosum	3.8	12	0.2	3.4	3.6	7.2	6	0.2	3.4	3.7
Populus koreana	3.9	10	0.2	2.9	3.0					
Larix olgensis	3.8	4	0.1	1.1	1.2					
Phellodendron amurense	4.5	1	+	0.3	0.3					
Betula costata						48.4	4	5.9	2.3	8.2
Picea jezoensis						51.4	1	1.6	0.6	2.2
Carpinus cordata						17.8	2	0.4	1.1	1.5
Salix sp						7.8	3	0.1	1.7	1.8
Acer ukurunduense						5.5	3	0.1	1.7	1.8
Total	10.4	350	100	100	200	21.3	176	100	100	200

Notes: N: Number of individuals; BA: Basal area /cm^2; IMPO: Importance value (BA%+N%); *: Dominant species.

The shrub layer had a similar trend to the tree layer, number of species in the disturbed plot were larger than that in the uncutting stand, i.e., 17 and 11 respectively. Number of dominant species with crown projection volume and importance value was equal in the two plots, each with 4, while it was larger in the selection cutting plot than that in the control by individual density, 6 versus 3 (Table 2). The selection-cutting plot was dominated by *Corylus mandshurica, Lonicera tatarinovii, L. chrysantha* and *Ribes maximowixianum,* and the control plot by *L. chrysantha* and *Acer barbinerve, Corylus* sp. And *R. maximowixianum*. In the selection-cutting plot, some species of shade intolerance, like *L. tatarinovii, Viburnum burejaeticum, Sorbaria sorbifolia, L. edulis* etc. were common and even had high density. These species were hardly found under closed canopy.

The composition of herb layer was differentiated by the predominant species, such as *Carex callitrichos* in the selection cutting plot and *Equisetum sylvaticum* in the control (Table 3). While some species abundant in the original forest, like *Meehania urticifolia, Aegopodium alpestre, Adoxa moschatellina* etc., were absent in the disturbed stand.

The Morishita similarity index between the two plots was low, 0.32 in upperstory, 0.48 in shrub layer, and 0.49 in herb layer, showing a high difference

Comparison of species diversity

As a whole, the species diversity in the selection-cutting stand was higher than that in the control. The dominance-diversity curves in the selection-cutting stand had long tails. Except at the herb layer, steepness was lower than that the control (Fig. 2).

In the tree layer, Shannon-Wiener index of number of individuals of the selection cutting plot was significantly higher than that in the control plot. And the evenness index had the similar trend (Table 4). The index calculated in basal area showed a reversed result, supporting the presumption that the natural forest had higher diversity and equivalence, comparing with the selection stand. This could also be indicated by the species-abundance relationship that the steepness of dominance-diversity curve was lower for stem density and higher in basal area, comparing with the control plot (Fig. 2). The sizes of DBH varied

drastically, was a large proportion of basal area. But small amount of individuals was in the large DBH classes. Enormous individuals in the small DBH classes recruited after the selection cutting. *Abies nephrolepis* was a species of shade tolerance and its stand had a large number of young trees, which were mostly distributed in the small DBH classes and thus the evenness was lower than that ranked by basal area.

Table 2. Shrub composition in the disturbed plots and the original plots.

	Logged				Unlogged			
Species	H /cm	V%	N%	IMPO	H /cm	V%	N%	IMPO
Corylus mandshurica	189	52.7*	15.4*	68.1*	191	17.0*	3.1	20.0*
Lonicera tatarinovii	90	13.5*	13.2*	26.8*				
Lonicera chrysantha	76	11.1*	16.3*	27.4*	58	29.6*	39.1*	68.8*
Ribes maximoviczianum	71	9.9*	18.5*	28.4*	70	12.7*	19.4*	32.1*
Syringa wolfi	189	5.4	3.5	8.9				
Acer barbinerve	146	3.7	3.5	7.2	54	23.4*	18.4*	41.8*
Rosa acicularis	103	0.9	3.1	4.0				
Euonymus pauciflorus	103	0.8	5.3*	6.1	95	1.0	1.4	2.4
Sorbaria sorbifolia	55	0.6	9.3*	9.9				
Viburnum burejaeticum	123	0.5	1.3	1.8				
Philadelphus schrenkii	85	0.3	0.9	1.2	150	2.5	4.8	7.3
Acanthopanax senticosus	62	0.2	2.6	2.8	84	0.2	1.7	1.9
Rubus crataegifolius	53	0.1	4.4	4.5				
Acer tegmentosum	45	0.1	0.9	1.0	109	7.9	5.1	13.0
Lonicera edulis	40	0.1	0.9	1.0				
Euonymus alatus	60	+	0.4	0.5				
Berberis amurensis	40	+	0.4	0.5	54	0.3	2.4	2.7
Spiraea chamaedrifolia					82	4.3	4.4	8.7
Lonicera maximowczii					79	1.0	0.3	1.3
Total	100	100	100	200	71	100	100	200

Notes: H: Mean height; V%: Relative projection volume; N%: Relative stem density; IMPO: Importance value (V%+N%); *: Dominant species.

Table 3. Herb species composition in the disturbed and the original plots.

	Logged			Unlogged		
Species	Relative stem density %	Relative density by projection volume %	IMPO	Relative stem density %	Relative density by projection volume %	IMPO
Carex callitrichos	88.8*	48.3*	152.8*			
Brachybotris paridiformis	1.7	38.4*	52.6*	4.4	27.0*	43.4*
Maianthemum bifolium	1.6	1.6	15.7	0.4	0.2	5.1
Milium effusum	2.3	2.9	14.6	11.6*	5.5	29.0*
Gramineae sp.	2.3	1.4	10.0			
Viola sachalinensis	0.3	0.3	8.4	1.2	0.2	7.4
Thalictrum tuberiferum	0.2	0.8	7.3			
Moehringia lateriflora	0.2	0.1	6.6	0.4	0.1	2.0
Cacalia hastata	0.1	3.1	6.3			
Oxalis acetosella	0.5	0.2	5.4	0.9	0.3	5.6
Carex siderosticta	0.4	0.7	4.2			
Carex sp.	1.3	0.8	3.6	4.0	1.0	10.9
Carex pilosa	0.1	0.2	3.5	0.3	0.2	1.9
Solidago virgaurea var. dahurica	0.1	0.1	3.3			
Aruncus sylvester	+	0.8	2.4			
Equisetum sylvaticum	+	0.2	1.8	47.3*	48.1*	108.9*
Trientalis europaea	+	+	1.6			
Meehania urticifolia				7.5*	11.3	27.8*
Aegopodium alpestre				12.3*	4.7	26.0*
Adoxa moschatellina				7.8*	1.1	20.8*
Stellarria bungeana var. stubendorffii				0.6	0.1	5.2
Corydalis ambigua				0.7	0.2	3.8
Pseudostellaria sylvatica				0.5	0.1	2.2
Total	100	100	300	100	-100	300

Notes: IMPO: Importance value (Relative stem density% +Relative density by projection volume% + Relative frequency); *: Dominant species.

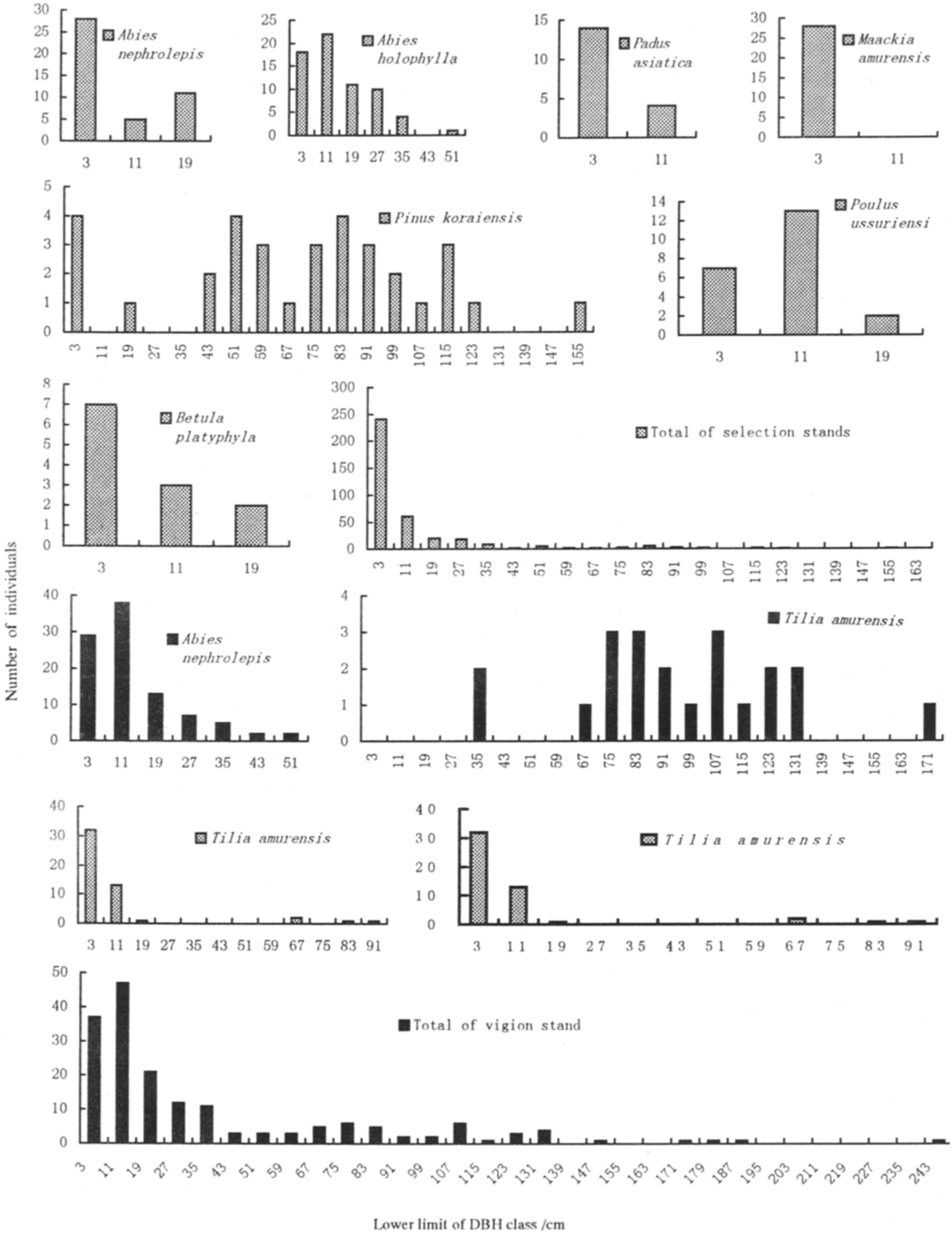

Fig. 1. DBH distribution of total stand and dominant species of the selection cutting and the virgin forest

Selection stand   Virgin stand

Table 4. Productivity and diversity indices in the cutting and the original stands.

Items	Logged		Unlogged	
	By N	By VOL*	By N	By VOL*
Tree layer:				
Number of species	15	15	12	12
Stems or Basal area	350	71577	176	126814
Shannon index	2.31	1.29	1.63	1.66
Simpson dominance	0.12	0.46	0.33	0.24
Evenness	0.85	0.47	0.66	0.67
Shrub layer:				
Number of species	17	17	11	11
Stems or VOL	22	82119978	294	59196266
Shannon index	2.35	1.55	1.77	1.81
Simpson dominance	0.12	0.32	0.23	0.2
Evenness	0.83	0.55	0.74	0.76
Herb layer:				
Number of species	17	17	15	15
Stems or VOL	6597	571030	2226	1113350
Shannon index	0.59	35458	1.78	1.44
Simpson dominance	0.79	0.38	0.27	0.32
Evenness	0.21	0.45	0.66	0.53

Notes: N: Number of stems; VOL: Projection volume /cm^3; *: By basal area for tree layer

Although the number of species in the later was more than that in the control plot, diversity index in the shrub layer calculated by crown projection volume, was higher in the natural forest than in the cutting plot. However, the index by number of individuals was higher in the disturbed plot than in the control (Table. 4). In the disturbed plot, the nonequivalent distribution of projection volume among species dominated by the large-sized shrubs such as *Corylus, Lonicera* etc., resulted in a lower diversity. On the other hand, the dominance-diversity curve ranked by number of individuals with lower steepness revealed that the disturbance provided equal opportunities for the establishment of the shrub populations (Fig. 2).

Diversity index of the herb layer calculated of number of individuals was significantly higher in the natural forest than that in the disturbed stand, and nearly the same as that of projection volume (Table 4). The herb layer in the disturbed plot was highly depressed by the dense shrub layer, which implies that herb layer was very sensitive to disturbance.

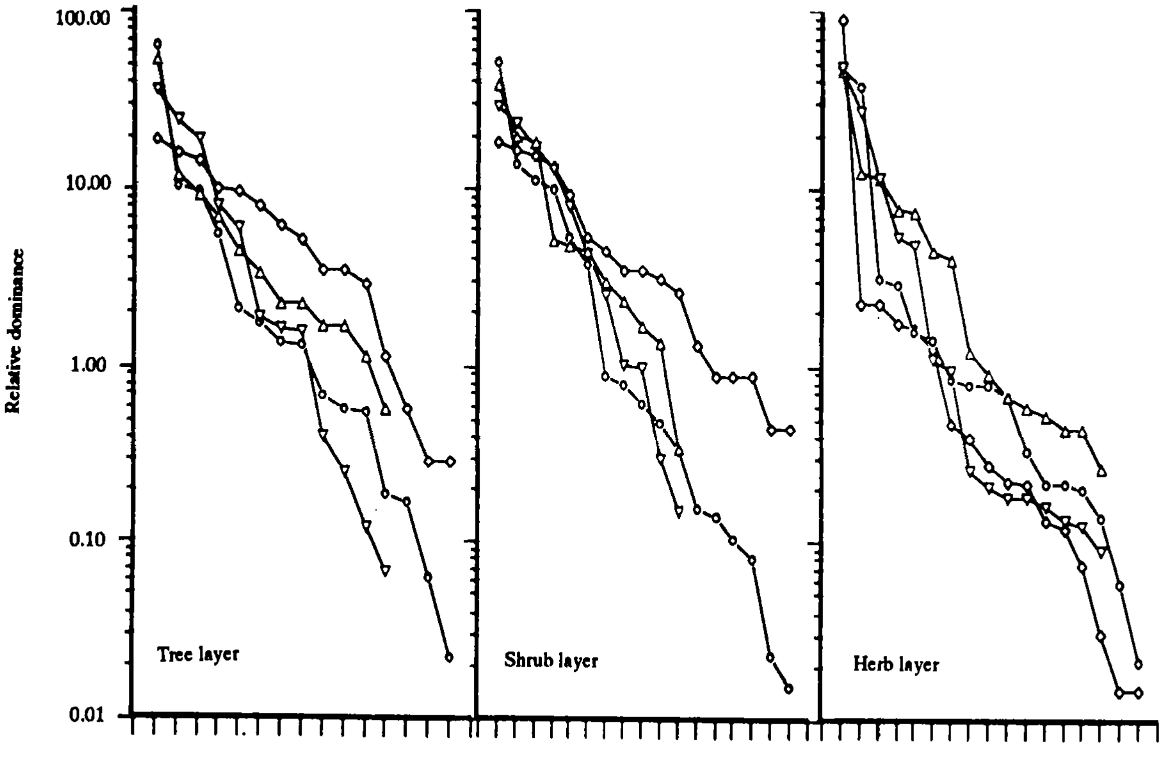

Fig. 2. Dominance-diversity curves of the selection cutting and uncutting forest.

◊: number of individuals in the selection cutting stand; Δ: number of individuals in the uncutting stand; O: basal area (projection volume for shrub and herb layers) in the selection cutting stand; ∇: basal area (projection volume for shrub and herb layers) in the uncutting stand.

The evenness index of tree and shrub layer had a similar trend. The index of stem density was higher in the disturbed stand than that in the non-disturbed stand, while the index calculated by basal area or projection volume was reversed and nearly equal by importance value. In the case of the selection cutting stand, the evenness index by any unit was lower (Table 4).

Discussion

Diversity-disturbance relationship

Precious studies on disturbance-diversity relationship have shown different conclusions largely depending on disturbance regimes (Elliott *et al.* 1994). The maximum diversity or species richness would appear later with the increase of disturbance intensity. The present study support-

ed the theory that biodiversity can be sustained by disturbances, which has been proved by enormous studies (Brokaw *et al.* 1989). Almost all species at tree, shrub, and herb layers were preserved and protected on the stand by selection cutting. Disturbances make the site more heterogeneous, and lead to a diverse state, such as richness in species composition and in spatial pattern of community. Similar to the natural disturbance, biodiversity can also be maintained by human disturbance (Franklin *et al.* 1987). However, the diversity is far dependent on the intensity and duration of a disturbance. In the natural-mixed forest consisting of many species with various eco-characteristics, such as shade tolerance and shade intolerance species, repeated clear-cutting may sharply decrease the biodiversity, even to nearly unrecoverable status. For the case in the study region, secondary forest established by natural succession after clear cutting was very poor in species richness. There were only two canopy species of *Betula platyphylla* and *Populus davidiana* even after fifty years of recovery. Furthermore, *Quercus mongolica* pure stand called plagioclimax, would appear if clear-cutting repeatedly disturbed the community. The forest might take centuries to get back to the original state. Diversity may sometimes recover quickly after clear cutting, but local extinction is often a critical consequence (Halpern *et al.* 1995). On the other hand, selection cutting based on the diversity sustaining theory can have a positive effect on forest ecosystem. Considering the number of species as the most important parameter for describing species diversity in the study area, the human disturbance of selection cutting has resulted in an increased diversity at all the strata described above. The forest-interior conditions are sustained by selection cutting, which is the most important basis for improving the community quality. Because the susceptibility to disturbance was different among species, climax species such as *Pinus, Tilia, Fraxinus* etc. were were released in small gaps, while pioneer species like *Betula*, *Larix* etc. were established in large gaps. This result supported the opinion that it changes progressively from climax species to shade-intolerance or nonclimax species with the distance increasing from forest interior to gaps (Canham 1989). Gaps are considered as the force of driving forest cycle (Whitmore 1989), and sustaining species diversity through edge effects (Williams-Linera 1990). Selection cutting is a way of creating gaps artificially, and it creates the similar effects as the natural disturbance does. However, concerning the aspect of biodiversity, a detailed study is necessary for finding the suitable intensity of selection cutting. A basic principle in utilization of forest resources should based on how fast its recovery was in term of both biodiversity and productivity. While determining the optimum selective cutting cycle, the selection rate must be controlled below the net productivity during the interval, and the community productivity must be kept high and sustainable. This should be practiced for not only in the canopy layer, but also all strata in the community.

Regeneration and disturbance

Regeneration is much determined by light condition. The increase of young-tree density (Table 1&Fig. 1) reflected that the regeneration was essentially prompted by selection cutting, which created different-sized gaps. Nonpioneer species germinate and establish primarily in the shade, but often recruit into canopy layer when juveniles are released from suppression (Martinez-Ramos *et al.* 1989). In the original forest of the study area, most of the dominant and codominant species in overstory were species of shade tolerance in the early stages and needed stronger light condition. Gaps or natural thinning provide suitable conditions for the regeneration by increasing light quantity. In the same way, selection cutting based on species characteristics creates a conducive condition for regeneration. This was supported by the DBH distribution of young trees, except the shade tolerance species of *Abies nephrolepis,* that had higher proportions in the selection cutting plot, but less or even nearly absent in the control plot (Fig.1).

For example, *Tilia amurensis, Acer mono, Maackia amurensis* ect. had large number of young trees in the disturbed plot, but almost absented from the original forest. Fig. 1 also showed that forest of *Pinus koraiensis*, a leading species, was lack of large saplings (DBH for 3cm~11cm). The DBH was slower than that of the deciduous species, so that the seedling and saplings have not recruited into the DBH class (>3cm) with 16-year-old growth. A clear cutting would abolish such a chance of establishment of climax species. The light requirement of *Pinus koraiensis* is changing rapidly with age increasing. Seedling requires strong light from then (Yao 1985). It rarely establishes under its own canopy or in the highly closed stand, but grow vigorously in secondary forest or in disturbed stand. This suggested that the disturbance provides a suitable light condition for the regeneration, and the species is a gap-dependent. Species like *Betula platyphylla, Popolus davidiana,* and *Larix olgensis* can only establish in large gaps or exposed land.

Because the forest-interior conditions are well sustained by selection cutting, reinforcement planting in such stand is a very successful way to make the restoration faster (Zhou 1982). This is a positive disturbance on the forest.

Recovery after disturbance

It is understood that forest does not necessarily have the highest productivity at climax phase. Similar to the growth process of individual tree, the community productivity generally follows the Logistic theory: the lowest productivity initially, and the highest before or near the climax. The growth rate of standing tree can be raised by creating more space and edges through selection cutting (Liu *et al.* 1980). In the management of such a forest ecosystem, for the purpose of keeping fast accretion, it becomes necessary to "disturb" the community through artificial thinning

or selection cutting, and to make suitable growing space for every individual.

In the selection cutting stand, individuals having high growing potential were in fast growing status, and a high speed of recovery in both productivity and species richness. The Structure, composition, and physiognowy of the original forest were sustained in the selection cutting forest. In a word, it has not gone beyond the resistance threshold or the recovery ability of the ecosystem, which is the basis of the recovery or reorganization. The basic constitution in the studied plot of selection cutting was sustaining although the number of large-sized individuals of each species had been much reduced. Therefore, the recovery of species richness after selection cutting is very fast. However, the spatial structure may take several decades to recover. The dominant age of trees in the original forest is about 150a old (Yang *et al.* 1994), and the maximum age may go over 300a. This means that some species may need, at least, several hundred years to reach the climax status for a secondary consociation, like *Betula platyphylla*-dominated forest, after clear cutting.

Problems

Although selection cutting has many advantages in the aspect of ecology, there are two factors affecting the accuracy of this study. One is that the changes in structure and species composition are based on two different plots, in which the unlogged plot is presumed as the previous status of the logged plot. Some considerable differences may exist even before the disturbance.

Another problem is that the sampling design has no replication. It is necessary that proper replication of samples and statistical tests be performed. These problems need to be checked in further study.

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